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A Case Study of Maize in Zambia

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Abstract

We examine the performance of maize import policy options in one of the poorest countries in Southern Africa. The results are shaped by unique features of Zambia's maize market: production that is limited by risk and highly variable returns, and local marketing margins that increase with imports and limit consumer trade gains. Results suggest that the market-stabilizing protection with the variable import levy (VL) may improve welfare, compared free trade or the current tariff regime. The VL also redistributes benefits to farmers and rural residents and away from urban consumers. Tax revenues could be used to fund transportation improvements or an urban consumer subsidy. Also, we estimate that market-led improvements in transport infrastructure, which would be conducive to more open trade policies, may be 25 years away.

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1. **Introduction**

For the long run, most Lower Income Developing Countries (LDC's) have agreed to the recent World Trade Organization (WTO) agreement. So most LDC's should eventually begin to convert agricultural protection to tariffs and reduce these tariffs towards free trade. But presently, LDC's secured Special and Differential Treatment provisions during the most recent Uruguay Round trade agreement. Specifically, LDC's have flexibility to slow down the agreed schedule of tariff and subsidy reductions; to use domestic subsidies for investment purposes and the benefit of poor urban consumers; and to forestall the removal of protection for commodities that are important in food security (Valdes and Young, p. 49).

This study looks at some agricultural trade policy options for the poor countries of Southern Africa. Our case study of maize in Zambia maize illustrates plausible commodity policy for food security; maize typically provides about three-fourths of calories in food balance sheets of countries in southern Africa; and maize is a dominant commodity in farm income determination (Mwanaumo et al.). Further, Zambia's isolation and limited infrastructure is common in the poorest developing countries. The trade policy options we consider are the existing 15% import duty, free trade, and three alternative versions of the variable levy (VL) with different levels of protection. A variable levy, with appropriate modifications away from its most familiar form, may serve the food security and development of these countries better than the existing tariff or free trade, at least for the next decade or so. Risk determines market allocations due to poor infrastructure and institutions, and the VL does provide market stability. Hence, our departure from the usual promotion of free trade policy.

Regarding organization, the first section discusses market allocation and welfare distribution in an importing country with risk and limited marketing infrastructure. The second section reviews econometric measurements and simulation procedures for the Zambian Maize market. The third section presents stochastic simulation results for the alternative policies. Conclusions are given in the last section.

2. Price and Trade Determination

We have considerable theoretical background and practical experience with the Variable Levy (VL) in agriculture. Mostly, we use the classic analysis of the variable levy (McCalla (1967a), p. 97; McCalla (1967b)). However, we do introduce risk, which modifies the allocation of resources and distribution of income. Based on Europe's experience with the VL, it is plausible that risk is an important part of the VL story. First, stability was important in the treaty of Rome (Marsh). Second, the VL was quite successful at improving productivity during the importing period in Europe's Grain sector (Gallagher, p. 768).

Consider price and trade determination for a small importing country that has limited grain market infrastructure. Under conditions of free trade, the excess demand schedule (ED^o) in panel b is defined by the supply schedule (S^o) and the demand schedule (D) in panel a. In panel b, the supply schedule for marketing services (S(M)) is upward sloping, reflecting the limited grain transport infrastructure. Hence, the import demand schedule ($D_M{}^o$) in panel c is the vertical difference between the excess demand schedule and the marketing services schedule. The free trade import level (M^o) is defined by the intersection of the import demand schedule and the perfectly elastic world supply (the world price, P_W).

A variable levy policy starts with a minimum import or target (Pt) that is administratively set for a marketing period. Then the variable levy (VL) is defined by the policy as the difference between the target price and the world price

$$VL = Pt - P_W$$

as long as the world price is less than the threshold price. However, given the instability on the world market, the variable levy shrinks to zero when the world price rises to the threshold price. Further, the variable levy typically remains at zero when the world price rises above the threshold price. In short, domestic importers buy at the threshold price under normal conditions or the world price when international prices are above the threshold price.

It is likely that the introduction of a variable levy will shift the domestic supply schedule outwards, from S^o to S^1, in panel a. The set target price removes the downside risk and reduces the price variability experienced by domestic producers. It is likely that the supply curve will shift outwards under conditions typical in the poorest LDC's; because the risk aversion of peasant farmers is well – documented; and because the infrastructure (storage, transportation) and institutions (futures markets) for risk shifting typically do not exist.

Hence, the effective import demand is the kinked curve shown in panel c. First, the import demand schedule shifts back (to D_M^1) with the risk reduction and supply schedule shift. Second, the import demand at the given threshold price Pt and D_M^1 define the vertical segment of the import demand at schedule at M^1. Above Pt, imports are defined by the schedule D_M^1 because the domestic marketers of the importing country are exposed to the world price.

Under conditions defined by supply schedule S^1 and the world price Pw in the diagram, the import level M^1 occurs. The import level is reduced, compared to the free trade import level, M^o. The reduced import volume increases domestic prices (P_z^1 instead of P_z^0). But the importing margin (P_z - P_w) declines in panel b, due to the outward shift in domestic supply. Part of the effect of the VL then, is to redistribute income from marketers to domestic producers.

3. Welfare Analysis

It may be possible for a small country to increase its overall welfare by replacing free trade with a variable levy (VL) under conditions where a supply shift from risk reduction occurs. To see this, take a look at the usual surplus areas. First, the area above the supply curve with risk and below the price line still approximates producers' returns over variable costs under conditions of price risk (Just et al., p. 501). So the producer surplus gain with the variable levy instead of free trade is:

$$)B_s = (A + B + C + D) - A \qquad = + (B + C + D).$$

The consumer surplus change, a loss, is

$$)B_d = - (C + D + E + F + G) \qquad = - (C + D + E + F + G)$$

because the price increases.

Domestic marketers also experience a loss due to reduced import volumes

$$)B_m = H - (H + I) \qquad = - I$$

Finally, the VL earns tax revenues equal to the difference between the target price and the world price, or area R

$$+ R.$$

So the net welfare gain is

$$)B = (B + R) – (E+F+G) – I.$$

That is, the country will gain overall if the producer risk benefit (B) and the revenue collections (R) exceed the standard trade surplus loss -(E+F+G) and the loss of domestic marketers –I.

4. Simulating the Market Effects of Trade Policy Changes

A dynamic model of the Zambian maize market is used to compare market positions before and after the introduction of a tariff policy. Adjustments occur gradually because of the lag between planting and production causes gradual adjustments of risk assessments and production plans. Econometric estimates provide estimates of supply and demand response. Relevant market effects, such as the effect of income and exchange rate fluctuation on demand, the effects of changing risk on area planted and yield, and the effect of import volumes on the domestic marketing margin, are taken into account.

Free Trade and Fixed Tariff: A maize model for the Zambian market under free trade or the fixed tariff is defined by equations (1) - (9) of table 1, using the first nine endogenous variables that are listed at the end of the table. The only difference between the free trade case and the fixed tariff is that the variable tz in equation (8) is tz=0 with free trade first, and tz=0.15 with the 15% tariff.

All maize prices in this model are expressed in local currency (Kwacha) and then deflated by the consumer price index. Further, the CPI is expressed with a value of 1.0 in 2002, which is the last year of available data and the baseline year for the simulation analysis. Thus, prices are in ‘today’s Kwacha’ - there is a considerable time lag in reporting baseline data for developing countries through the UN.

Equations (1) – (4) together determine maize production. Area [equation (1)] is positively related to maize price. Area also depends on risk, which is measured with a period-by-period calculation of the standard deviation of recent maize profits (returns over fertilizer costs). Area also depends on lagged area, possibly reflecting incomplete adjustment to the most recent market conditions.

Equation (2) is a production function that describes the technical relation between maize yield and the fertilizer application rate; linear and quadratic fertilizer terms are included to approximate the extent of diminishing returns to the fertilizer input. A linear trend term was also included to estimate the effects of improving technology.

Equation (3) is the implied fertilizer application rule from the profit-maximizing condition that the value of the marginal product of fertilizer equals the fertilizer price, the marginal product taken from equation (2). We assumed that the gap between the value of the marginal product of fertilizer and the fertilizer price during the most recent 7 years before the 2002 baseline year defines a risk term associated with the present market environment (Rf). This risk term was reset at zero in simulations of the variable levy, because this is what happened in european grain markets under similar circumstances. The recent gap between actual and profit-maximizing fertilizer application is about 25 kg nitrogen/ hectare. Current nitrogen use in Zambia, at about 45 kg/ha, is considerably less than most developed countries and below the range where fertilizer causes environmental problems (Bumb and Baanate).

Equation (4) defines production as the product of acreage and yield.

Equation (5) is derived from a conventional per capita demand function that depends on the maize price and consumer income. GDP was used as a proxy for Consumer income or personal consumption expenditures.

Equations (7) to (9) are price transmission relationships. Equation (9) is a conventional relationship for the relationship between the U.S. price and the South African price of white maize-the independent variable in equation (8) is the U.S. price expressed in terms of South Africa's currency (the Rand). Equation (7) merely multiplies the South Africa price by the Zambian exchange rate to arrive at the import (world) price expressed in local currency units. The South African price was also multiplied by one plus the existing 15% maize import duty for estimation, and then removed for free trade simulation.

Equation (8) specifies that the domestic wholesale price depends on the import price and the maize import volume. The presence of import volume in a price transmission relationship occurs due to the limited supply of transportation services. The second term defines the import price- a regime change defined by the dummy variable Dw is explained below with the variable levy analysis.

Equation (6) is an identity that imposes a balance between supply and demand.

Estimations of market relationships prepared for this study used the most recent data available. Statistical properties of these estimates are given in the appendix.

Variable Levy: Now the minimum import price is set administratively at the threshold price each year. Accordingly equation (10), which defines the administratively set target price, and equation (11), which defines the size of the variable levy, are included in the simultaneous system with Pt and VL as endogenous variables.

To address the criticism that administered pricing and stabilizing schemes do not adjust to market forces, we assumed that the threshold price is set every year as a weighted average of last year's threshold price and last year's market price. Specifically, we set $\exists_{10} = 0.9$ and $(_{10} = 0.1$ for threshold price adjustments that stabilize market fluctuations but still adjust slowly to long run market trends. Further, three varieties of the VL system were specified according to the condition that the long-run equilibrium threshold price, Pt^e, and long-run equilibrium world price, Pw^e, reduce (10) to

$$Pt = \forall_{10} / (1-\exists_{10}) + Pw,$$

when (= 1 - ∃, and when the world price is at rest.

First, a purely stabilizing scheme features $\forall = 0$ and a tendency for the threshold price to come to rest at the world price: $Pt^{e}=Pw^{e}$. Second, a moderately stabilizing scheme has the same average tax as the existing 15% duty when $\forall_{10}= 10.25$, and $Pt^{e}=102.55 +Pw^{e}$. Third, a highly protective scheme features $\forall_{10} =50$ and $Pt^{e}= 500 + Pw^{e}$.

Finally, two dummy variables in equation (8) define the regime changes that occur with the variable levy policy. First, in the case there $Pw_t > Pt_t$ the variable levy shrinks to zero and a free market regime occurs because the dummy variable, Dw=1. Second, under occasional surpluses domestically administered prices produce a variable export subsidy without regime change in the model. Then the dummy variable, Dx=0 sets the domestic marketing margin at the level that occurs without imports.

Dynamic Risk Adjustment: Conventional estimations of producer risk response specify that area responds to dynamically adjusting expected values and variances of prices or returns. Also, adaptive expectations are hypothesis for measuring adjustments of expectations and risk (Pope and Just, P. 746). We use approximations for the adaptive expectations expected profit and variability formulas that can be estimated with linear regression methods (Ryan, p.). Specifically, we estimate risk using a moving standard deviation of maize returns over fertilizer cost is calculated after the model is solved each year. First, maize returns per hectare for period t are

$$\pi_t = Pz_t Y_t - Pf_t (F_t / A_t).$$

Then expected profits for period t are calculated as a moving average of recent profits

$$\overline{\pi}_t = (1/3)[\pi_{t-1} + \pi_{t-2} + \pi_{t-3}].$$

The period i observation for the standard deviation of profits is

$$R_t^i = |\pi_t - \overline{\pi}_t|.$$

So the risk measure for period t,

$$R_t = (1/2)R_{t-1}^i + (1/3)R_{t-2}^i + (1/6)R_{t-3}^i \text{ , } 1/2 + 1/3 + 1/6 = 1 \text{ ,}$$

adjusts over time, given the market outcomes from previous years. So acreage and output will also adjust, to the extent that a policy changes the risk in the market environment. Notice that we use a broad definition of risk that includes variability in maize prices, maize yields, and fertilizer prices.

5. Stochastic Simulations

The extent of external instability affecting Zambia's maize market is determined by the exogenous variables. First, we determined that the yield disturbance is approximately a normal distribution. Otherwise, we estimated a first order autoregressive process for each exogenous variable. In this fashion, the plausible range of variation in local weather, the macro economy, and international factors is specified. Then stochastic simulations are based on plausible estimates for external variability and the adjustments that are likely to occur within the maize market. These simulations are based on a 100 year experiment that draws random outcomes for the stochastic component of each exogenous variable, and then calculates a solution for the simulation model for each year and a given set of random outcomes.

The main results of the variability measurement analysis for exogenous variables are given in table 1. The coefficient of variation, expressed as a percentage of the trend value for the baseline year, ranges from twenty percent to one hundred-twenty five percent. Further, the exchange rates and the fertilizer price have a significant auto-correlation coefficient, indicating a cyclical pattern of disturbances. The other three series, yield, GDP, and U.S. maize price, did not show strong cyclical behavior over the past 20 years. Estimation details are given in appendix b.

Generally, the trend terms from the time-series analysis could not be supported by other available projections to be used in 100 year simulations. Instead, we used generally accepted assessments of African growth trends for GDP at 3.2% annually, and population at 1.3%annually (United Nations, p. 31). We did retain the linear trend effect in the estimated maize yield equation. However, it is unlikely that the downward trend in corn and fertilizer prices will continue steadily for the next century, due to increase in demand in these commodity markets. We also assumed that there would not be a long-term deterioration in the competitive position of the Zambian currency relative to the U.S. and South Africa. Thus, the remaining long-term growth trends in the simulation analysis define the balance between linearly improving yields and the geometrically growing demand resulting from income and population growth.

6. Measuring Welfare Effects

The welfare evaluation in this article is based on surplus measures and income indicators calculated from the market price and quantity estimates of the simulation model. Consumer surplus is calculated as the usual geometrical area above the price line and below the demand curve. Similarly, marketers' surplus is calculated with the geometrical area below the price line and above the MC curve. But farm producer welfare is measured by the actual income, returns over variable costs, instead of using a geometrical area; revenues are maize price times output from model solutions. Expenditures are the product of fertilizer price and fertilizer utilization.

Farm producer income should also be adjusted to account for risk. Because of the lack of Zambian farm data, we use an estimated utility function from a study of risk preferences among peasant farmers in Brazil (Dillon and Scandizzo). Dillon and Scandizzo surveyed 130 small subsistence farmers about alternative risky farm production choices—then they estimated utility functions. We used the quadratic utility function estimate from the Brazil study. Specifically, we converted the estimated utility function from local currency in Brazil during 1972 to local currency in Zambia in 2002. Then we adjusted profit estimates from the simulation for risk, using our utility function estimate. The procedures are explained below.

First, adjust the Brazil estimate for inflation and convert to Zambian local currency. The average risk coefficient ($b = 6 \times 10^{-6}$) approximates risk preferences for Brazil's farmers (Dillon and Scandizzo, p 429);

$$U(B) = B - b\,B^2,$$

where B is the peasant family's income, expressed in 1972 cruzeiros. Next, we find the income with the highest level of utility for the Brazilian family:

$$U'(B) = 0 \;\Rightarrow B^* = (1/2b) = 8{,}333 \text{ 1972 cruzeiros, when } b = 6 \times 10^{-6}.$$

To find the equivalent income in Zambia in 2002, convert to dollars using the 1972 Brazil exchange rate, then use the U.S. CPI for the equivalent income in 2002 dollars, and then use the 2002 Zambia exchange rate for the equivalent current income in Zambia. Thus,

$$B^* = (1/2b) = 35{,}108{,}139 \text{ 2002 Kwacha (or } b = -\,0.14 \times 10^{-7}).$$

Second, the certainty equivalent income (B_c) is defined by the condition that the expected utility of the risky prospect equals the utility of some certain income level:

$$E[U(E, S)] = U(B_c).$$

For the quadratic function above the expected utility for a risky prospect with mean E and standard deviation S is

$$EU = E - b\,(E^2 + S^2).$$

Then the condition for certainty equivalent income becomes:

$$E - b\,(E^2 + S^2) = B_c - b\,B_c^{\,2}.$$

Using the quadratic formulae, rearranging and choosing the upper root gives

$$B_c = B^* + \{\, B^{*2} - 2\,B^* \;[\, E - b\,(E + S^2)\,]\, \}^{1/2}.$$

This certainty equivalent income formula was used with outputs from the simulation model to approximate the certainty equivalent income. Actual farm income, expressed on the basis of a family of seven, was used to approximate E. Meanwhile, the risk variable approximates S. The income adjustments obtained in this fashion led to discounts on the raw farm income measures ranging from 1% to 14%, with an average of 3.1% for the first 10 years of the baseline simulation.

These risk adjustments are probably very conservative. The quadratic utility function, usually considered an expedient approximation for use when major changes in the income level are not involved, exhibits increasing (decreasing) risk aversion with increasing (decreasing) income levels. And the income level of the Brazil family, 3,362 of ’02 dollars, is considerably higher than the typical Zambian farm Family, 1,009 ’02 dollars (Michigan Survey).

7. Results

We compare simulation experiments with alternative policies but the same set of external growth trends and random events. In this fashion we can rank the market and welfare outcomes under the alternative policies.

We consider five alternative policies. The baseline retains the existing 15% import duty in the maize market; it is useful to examine how Zambia’s maize economy will evolve over the next generation, without policy change, in an environment of improving technology, growing population, and increasing GDP. We refer to the baseline as scenario (1). The free trade scenario is considered because it is the ultimate goal of the GATT and the immediate goal of many trade policy analysts. We refer to free trade as scenario (2). Three qualitatively different versions of the variable levy are considered. A purely stabilizing version with a threshold price will converge to the world price if world price shocks cease, referred to as scenario (3); a VL with an average tariff rate that equals to the baseline 15% tariff, referred to as scenario (4); and a European-style VL that sets the threshold price well above the world market price, referred to as scenario 5.

Market Outcomes: A plausible evolution of the maize market under the baseline policy and growth assumptions is shown in figure 2. Production growth even exceeds demand growth over the next decade or so. Under the particular realization shown, there is even a small exportable surplus in the second decade. But the exponential growth of population and GDP begins to exceed production growth after year 30, and clearly dominates by year 50. Then Zambia's imports will grow to the 2-3 million MT range in the second half of the century.

Comparing the threshold prices in scenarios 3, 4 and 5 to world prices in fig. 3 shows that the three threshold prices are similar in their year-to-year adjustments, but the levels are quite different:

- The threshold price for the purely stabilizing policy (scenario 3) has the lowest level. The variable levy is discarded for free market operation in about one-half of the years, a situation indicated by a world price that exceeds the threshold price.
- The variable levy that is most comparable to the existing tariff (scenario 4) has a moderately higher level than the stabilizing policy—this policy reverts to a free market in about one-third of the years.
- The threshold price for the Euro-policy (scenario 5) is about 70% higher than the lowest threshold price. Consequently, the variable levy is abandoned in only three years of the 100 year sample.

Table 3 shows how market outcomes compare to free trade (scenario 2) for each of the four alternative policies:

- All of the alternatives to free trade increase production and reduce imports, as expected.
- Generally, protection reduces demand and increases domestic prices, but there are a few surprises:
    - The stabilizing form of the VL policy actually reduces the average of domestic prices, because high tariffs are not passed to the domestic market on top of moderately high world prices.
    - The most protective version of the VL policy (scenario 5) actually increases average consumption. One explanation hinges on the long lags in acreage adjustment; protection keeps production high through low price periods on the world market.

Then a high production level can be sustained through a subsequent high-price period on the world market with a relatively low threshold price.

- The main difference between the baseline 15% tax (scenario 1) and the VL policies (scenarios 3, 4, and 5) is the extent of import substitution:
  - The fixed tariff rate (scenario 1) produces a moderate 6% reduction in imports, compared to scenario 2.
  - The import substitution under the VL policies (scenarios 3, 4, 5) ranges from 20% to 46%.

Table 4 contains the averages of simulated values of the risk measure for each scenario. It shows that risk has a role in the estimated production adjustments:

- The ranking of risk environments from highest to lowest is: fixed tariff rate (scenario 1), free trade (scenario 2) and variable levy (scenarios 3 through 5). Comparing the existing tariff rate (scenario 2) to the variable levy, it appears that income variability could be reduced about 15% by moving to the VL.
- All versions of the VL policy give about the same risk environment over the first 25 years, but the Euro-style VL (scenario 5) reduces risk somewhat more over the 50-year period.
- Hence, the production increase and import substitution with the VL policy, demonstrated above, is mostly explained by risk reduction for the stabilizing and mildly protecting versions. But price and risk work together for the largest import substitution in the Euro-style policy.

Welfare: The welfare results reported in this section have two components. First, net welfare indicates the overall performance of each policy. Second, the benefit distribution analysis identifies groups that lose and gain.

The net welfare (the sum of consumer surplus, marketer surplus, risk-adjusted farm income, and government tax revenue) was calculated for each policy and every year in the simulation experiment. These calculations are summarized in figure 4, which contains the difference between the net welfare for a given policy and the net welfare for free trade. The lines in this diagram give the net welfare gain for the fixed rate tariff (scenario 1), the stabilizing VL (scenario 3), the moderately-supporting VL with the same average tax rate as the baseline (scenario 4), and the highly protective VL (scenario 5).

Perusal of figure 4 suggests:

- All of the tariff policies are preferred to free trade in the sense that net welfare is higher.
- All of the alternative policies perform about equally for the first decade of the simulation.
- The most protective form of the VL (scenario 5) emerges as the policy with the highest net welfare gain during the second and third decade. The magnitude of the gain for switching away from free trade is not large; it is about 1.2% of GDP.

The distribution of welfare gains for urban and rural residents is approximated using sector surpluses, and a few plausible assumptions about groups that are likely to realize the benefits-see table 5. The average consumer surplus for each policy change from free trade is divided by the population to obtain a consumer surplus change for each person in the country in column (IV); the consumer surplus loss with tariff policies ranges from –8,469 ’02K with the fixed rate tariff (scenario 1), to -35,492 ’02 K with the highly protective version of the VL (scenario 5). Next, the farm income gain for the sector is divided by the farm population, and given in column (V); farmer gains from risk reduction and price supports range from 10,732 to 56,634 '02K per farm resident according to the extent of protection. Further, combining farm income gains and consumer surplus losses in column VI, shows that the farm income gain more than offsets the consumer surplus loss. Consequently, all of these policies provide income support to farmers, up to 21,142 ’02 K per farm resident. In column (III), we divide marketer surplus change by the urban population. Column (II) combines the consumer and marketer surplus. Column (I) contains tariff revenues, expressed as an average for urban residents.

There are three main conclusions from the distribution analysis of table 5:

- There are rural gains and urban losses when free trade is replaced with tariff protection.
- The policies are ranked from worst (best) to best (worst) for producers (consumers) as follows: fixed rate tariff (scenario 1), the stabilizing VL (scenario 3), the moderately protective VL (scenario 4), and the highly protective VL (scenario 5).
- The tax revenues generated by these tariff policies would be sufficient to offset the net loss for 1/3 to 1/2 of the urban residents, using a targeted subsidy.

8. Critical Role of Marketing System

The WTO agreement that includes special and differential treatment provisions for LDC's also includes provisions to build infrastructure to expand their trade opportunities. In Zambia, similar to most LDC's, the limited supply of marketing services is a critical trade-determining aspect of the maize market. It is important to know at what point growing import demand will overload the local marketing system, produce wide marketing margins, and perhaps induce some transportation infrastructure improvements in the open market. Towards this end, we look at the U.S.-Zambia marketing margin, ocean freight, potential reductions in local transport costs that could occur with an infrastructure investment, and the cost of a road.

In figure 6, we have estimated marketing returns as the difference between Zambia and U.S. wholesale prices of white maize. The horizontal lines are the sum of U.S.-Africa ocean freight and African land transport costs. Both cost estimates use the same ocean freight rate of $1.018/bu (Grain Transportation Report, p.15). The 'pre-investment' estimate of African transport costs is $2.31/bu. The post-investment rate, $0.853/bu. Hence, we estimate that investment could reduce the local component of transport costs by $1.457/bu. Making a unit conversion, the freight cost saving rate in the event of improvement is $57.56/MT.

The reduction in local transport costs is extrapolated from margin changes that occurred in a region of Brazil that recently improved its exporting capacity. Specifically, the pre-investment level of transport cost is the soybean price spread from the remote 'Mato Grosso' region of Brazil to export port before improvements in their transport system (Schnepf et al., p. 48; Larson). The distance to this remote region of Brazil, 1100 miles, is the same as the distance on the dominant South Africa-Zambia import route. The post-investment transport rate, \$0.853/bu is the truck rate (\$.001723/bu/mile) times the Nacala Port-Zambia distance (495 miles). Transportation on this shorter route is technically feasible (Railroad Development Corporation). The post-investment rate estimates the transport cost if an operational road or train was built. A generic truck transport rate reflects internationally competitive equipment and energy markets; the truck rate is about the same in Brazil and in the U.S. (Grain transportation report, p. 18).

The cost of a new road through Malawi may be about \$410 million, based on the cost of a slightly shorter road in Ethopia (Adis Tribune). This leads to an annual payment of \$36.4 million if a 30-year mortgage with 8% interest can be secured to build this road.

Given the mortgage costs and the annual savings rate, we can infer a minimum maize import volume that would balance the transport cost savings and mortgage costs:

Freight Saving Rate	x	maize import volume	=	annual mortgage payment

or

$$\frac{\$57.56}{\text{MT}} \quad \text{x} \quad X \text{ mil MT} \quad = \quad \$36.4 \text{ mil}$$

Thus, the threshold import volume that would likely attract private capital to make the transportation improvement is X = 0.65 million MT. Given our baseline import scenario in figure 2, it may be 20-25 years before the private sector would be seriously interested in this infrastructure investment; because imports do not consistently exceed 0.5 million metric tons; and because the margin does not consistently exceed post-investment transport costs.

9. Conclusions

This study has looked at import policy alternatives for a Food Security Commodity in one of the poorest countries in Southern Africa. We have looked at policies and how they might serve the food security objective and the net welfare.

The unique features of maize market structure in Zambia have a bearing on trade policy performance. First, production is reduced by high variability of returns and limited by long response lags. Second, marketing margins increase with imports and limit the usual consumer gains from trade expansion.

Theory suggests that market-stabilizing protection may improve overall welfare. Simulation results suggest that all forms of protection do lead to a moderate welfare improvement over free trade. But all forms of the VL give more extensive import substitution than the baseline fixed tariff rate. Compared to free trade, the VL redistributes benefits towards farmers and rural residents, about two-thirds of the population, and away from urban consumers, about one-third of the population. In turn, the tax revenues generated by the variable import levy could be used to fund a domestic consumer subsidy for the poorest ¼ to 1/3 of urban residents. Alternatively, transportation improvements could be financed with the annual revenues from the VL operated with moderate protection

Eventually, we expect that the small-scale marketing system will be replaced with a more modern transportation system. Then increases in price variability in response to changing import volumes would be reduced. But our estimates suggest that market-led improvements in transport infrastructure that are based on maize imports may be 25 years away-the import volumes are not sufficient yet, despite wide marketing margins.

In the short or intermediate term, protection with the VL may serve a poor African country such as Zambia well, especially if the tariff revenues are redistributed as food subsidies to the poorest urban residents. However, provisions that allow threshold prices to adjust slowly towards the market are essential to provide stability without prolonged departures from world price levels. Further, the country will probably outgrow the VL policy when the import market grows enough for a modern transportation investment. And history suggests that the country will have difficulty discarding the VL when the time for free trade finally does arrive.

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Endnote

1. The mean value area response elasticity is 0.58 for the short run, and 2.9 for the long run. Foster and Mwanaumo obtain the same estimate for the short-run: 0.54 . However, their long run estimate, at 1.57, is considerably smaller than ours.

Table 1. Simulation Model for Zambia's Maize Market

1.	A_t =	$_1 + \hat{}_1 Pz_t - (_1 R_t + 2_1\ A_{t-1}$	Area
2.	Y_t =	$_2 + \hat{}_2 \left(F_t / A_t\right) - \gamma_2 \left(F_t / A_t\right)^2 + \theta_2 T + \varepsilon_t$	Yield
3.	F_t =	$\left[\beta_2 / 2\alpha_2 - Rf_t + \beta_2\ Pf_t / Pz_t\right] A_t$	Fertilizer
4.	Q_t =	$A_t\ Y_t$	Production
5.	D_t =	$N_t\ [\ \ _5 - \hat{}_5\ Pz_t + (_1\ GDP_t\ ]$	Demand
6.	$I_{t-1} + M_t + Q_t\ =\ D_t + X_t + I_t$		Identity
7.	Pw_t =	$Pa_t\ Ea_t\ (1 + t_z)$	Zambia Import Price
8.	Pz_t =	$_8 + \hat{}_8 [Pw_t\ Dw_t + Pt_t\ (1 - Dw_t)] + (_8 M_t Dx_t$	Zambia Wholesale Price
9.	Pa_t =	$_9 + \hat{}_9 Pu_t\ Eu_t$	South Africa Price
10.	Pt_t =	$_{10} + \hat{}_{10} Pt_{t-1} + (_{10}\ Pw_{t-1}$	Zambia Threshold Price
11.	VL_t =	$Pt_t - Pw_t$	Variable Levy

Endogenous variables (2002 value):

1. A_t :	Area harvested (430,000 ha)
2. Y_t :	Yield (1400 kg/ha)
3. F_t :	Fertilizer (34,498,000 kg)
4. Q_t :	Production (602,000 mt)
5. D_t :	Demand (1,383,573 mt)
6. M_t :	Imports (300,000 mt)
7. Pz_t :	Wholesale Price (914.85 2002 Kwacha/kg)
8. Pw_t :	World or import Price (683.67 2002 Kwacha/kg)
9. Pa_t:	South Africa Price (1.4328 2002 Rand/kg)
10. Pt_t:	Threshold Price (741.30 2002 Kwacha/kg)
11. VL_t:	Variable Levy (132.25 2002 Kwacha/kg)

Exogenous Variables (2002 value):

γ_t :	Yield Disturbance (-527.6 kg/ha)
T :	Trend (0 in 2002)
R_t :	Risk (732,133 2002 Kwacha/ha)
Pf_t :	Fertilizer Price (2,947.06 2002 Kwacha/kg)
Rf_t :	Risk, Fertilizer (514.6)
N_t :	Population (10.698 million people)
GDP_t:	Gross Domestic Product (16,260,400 Kwacha)
I_t :	Ending Inventory
Ea_t :	Zambia-South Africa Exchange Rate (477.155 2002 Kwacha/2002 Rand)
Pu_t :	U.S. Price (White Corn) (0.1200 2002 $/kg)
Eu_t :	U.S. – South Africa Exchange Rate (8.626 2002 Rand/2002 $)
t_z :	Zambia's Fixed Maize Import Duty (15% with baseline policy)

$$D_w = \begin{Bmatrix} 1;\ \text{for Pt} < \text{Pw and variable levy policy} \\ 0;\ \text{for Pt} > \text{Pw and variable levy policy} \end{Bmatrix} \quad D_w = \{1;\ \text{for free trade or fixed tariff}\}$$

$$D_x = \begin{Bmatrix} 1;\ \text{for M} > 0 \\ 0;\ \text{for M} < 0. \end{Bmatrix}$$

Table 2. Sources of Zambian Maize Market Instability

Variable	Units	2002 Trend	RMSE	Coef. of Variation	First Order Autocorr. Coef.
Zambia :					
Maize Yield	kg/ha	1700.0	354	20.8%	0
Real GDP	%) (0/1), ’02 Kw	0.0526	0.0658	125.0%	0
Exchange Rate	‘02Kw/’02R	669.24	186.75	27.5%	0.63
United States:					
Maize Price	‘02$/kg	0.0894	0.0367	41.5%	0
Exch. Rate (So. Africa)	‘02R/’2$	6.941	0.874	59.5%	0.60
Fertilizer Price	‘02Kw/kg	2491.0	3533	60.8%	0.61

Table 3. Average Changes in Market Outcomes, Compared to Free Trade (Scenario 2)

	--In Percent, 0-100	--		
	Base (Scenario 1 !Scenario 2)	VL$_a$ (Scenario 3 !Scenario 2)	VL$_b$ (Scenario 4 ! Scenario 2)	VL$_d$ (Scenario 5 ! Scenario 2)
Production	+0.99	+4.46	+5.30	+8.91
Demand	-0.32	-0.29	-0.45	+0.38
Imports	-6.07	-20.57	-25.12	-45.78
Wholesale Price	+6.00	-0.38	+2.75	+15.18

Table 4. Average Risk Measures[1]

Policy	Free Trade (ft) (Scenario 2)	Baseline 15% Tariff (base) (Scenario 1)	----Variable Levy---- =0 (Scenario 3)	=10 (Scenario 4)	=50 (Scenario 5)
25 year	361.30	399.80	343.00	341.40	341.95
50 year	766.30	799.00	758.42	750.25	723.43

[1]Standard deviation of maize revenues over variable (fertilizer) costs, in '02 kwacha / hectare

Table 5. Distribution of Average Annual Welfare Changes vs. a Free Trade Policy

Policy:	(I) Gov't Revenue per urban resident	(II) Net Surplus per urban resident	(III) Marketer Surplus per urban resident	(IV) Consumer Surplus per person	(V) Farm Income per rural resident	(VI) Net Surplus per rural resident
	----------in 2002 Kwacha----------					
Baseline 15% Tariff (Scenario 1 less Scenario 2)	+5,625	-11,304	-2,835	-8,469	+10,732	+2,263
Variable Levy, LR Tax=0 (Scenario 3 less Scenario 2)	+8,169	-17,415	-9,427	-7,988	+11,933	+3,945
Variable Levy, LR Tax=10.26 Kw/kg (Scenario 4 less Scenario 2)	+10,521	-23,570	-11,422	-12,148	+18,776	+6,628
Variable Levy, LR Tax=50 Kw/kg (Scenario 5 less Scenario 2)	+17,523	-54,497	-19,005	-35,492	+56,634	+21,142

Notes:
1. Nominal and real exchange rate in 2002 was 4,771.3 Kw / U.S.$
2. Nominal and real per capita GDP in 2002 was 1,519,950 Kw / person
3. The rural (farm) population in 2002 was 6.866 million people
4. The urban (non-farm) population in 2002 was 3.812 million people

Figure 1. Price and Trade Determination with Variable Levy

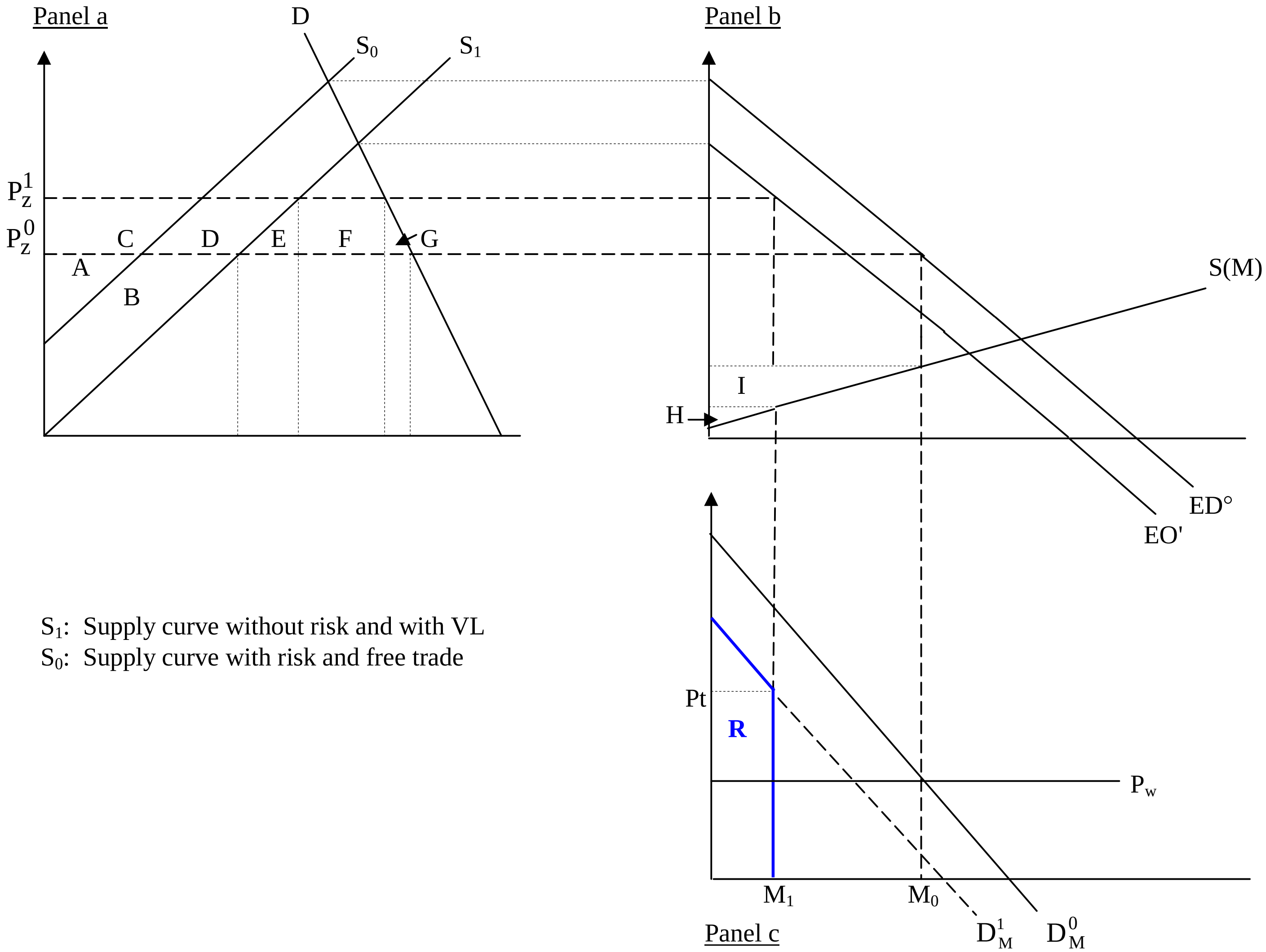


Figure 2. Zambia Maize: Simulated Production (Q), Demand (D) amd Imports (M)

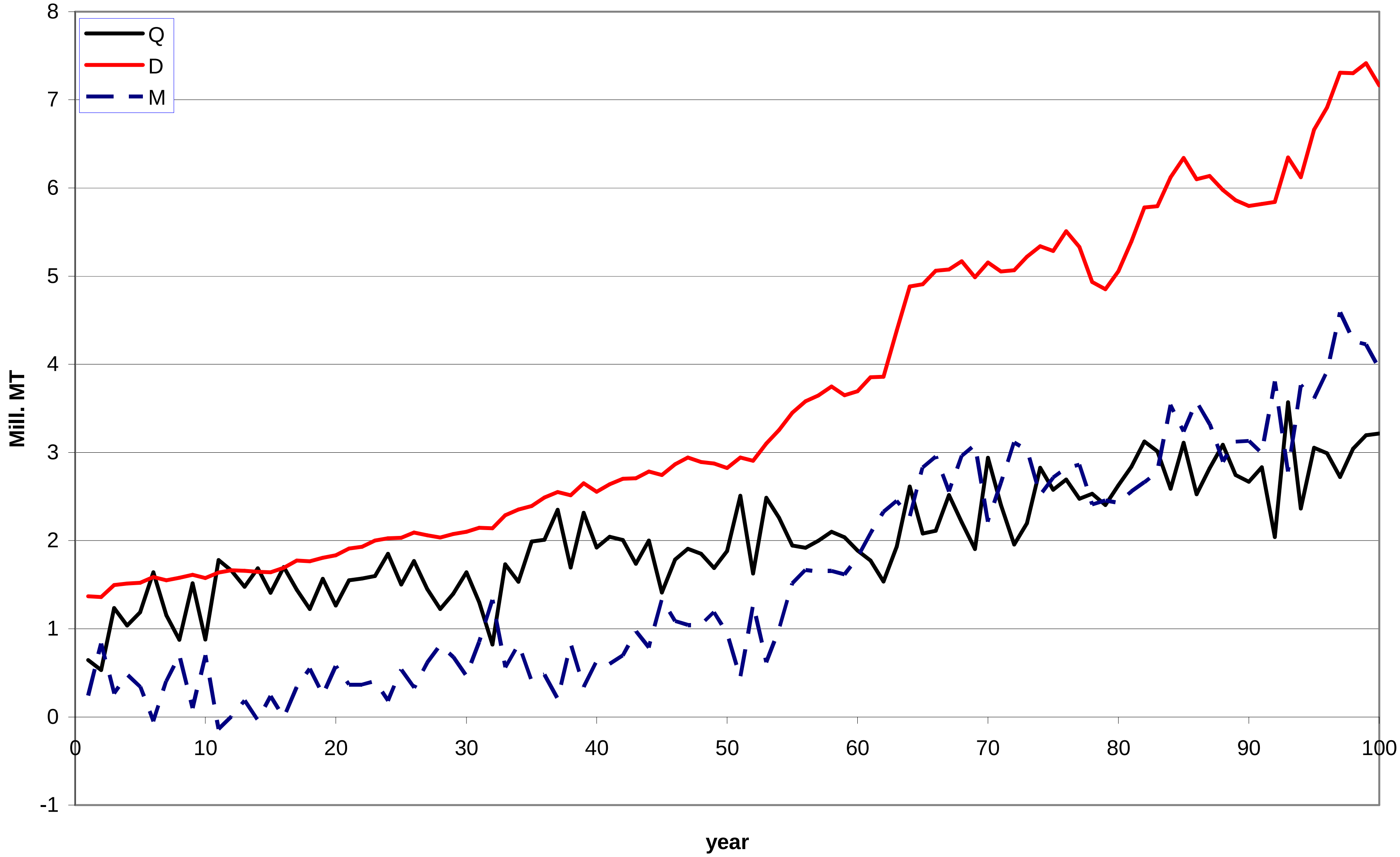


Figure 3. Import Price (Pw) and Threshold (Pt) Price Comparisons with Alternative Threshold Price Policies

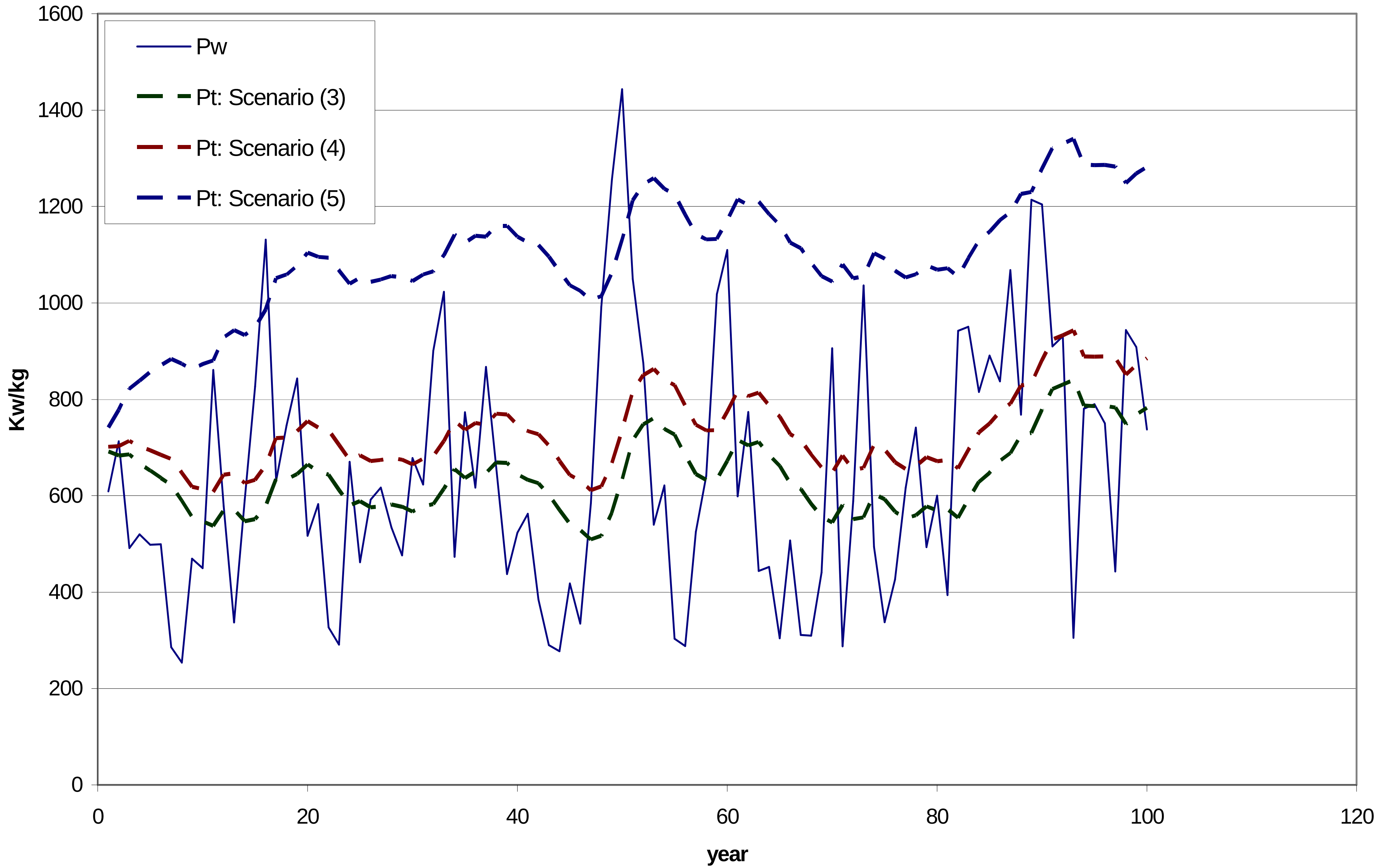


Figure 4. Net Welfare (NW) Gain over Free Trade

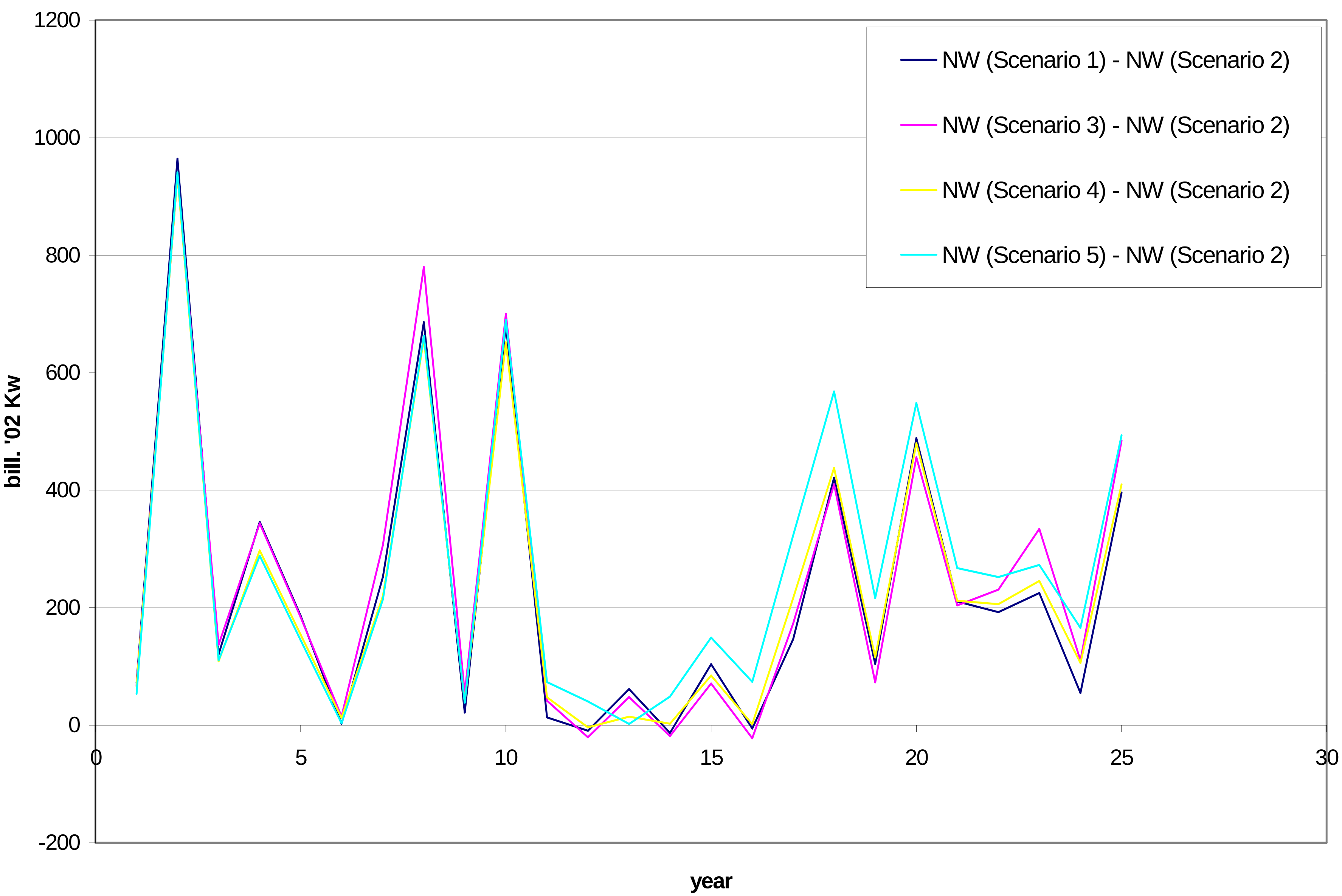
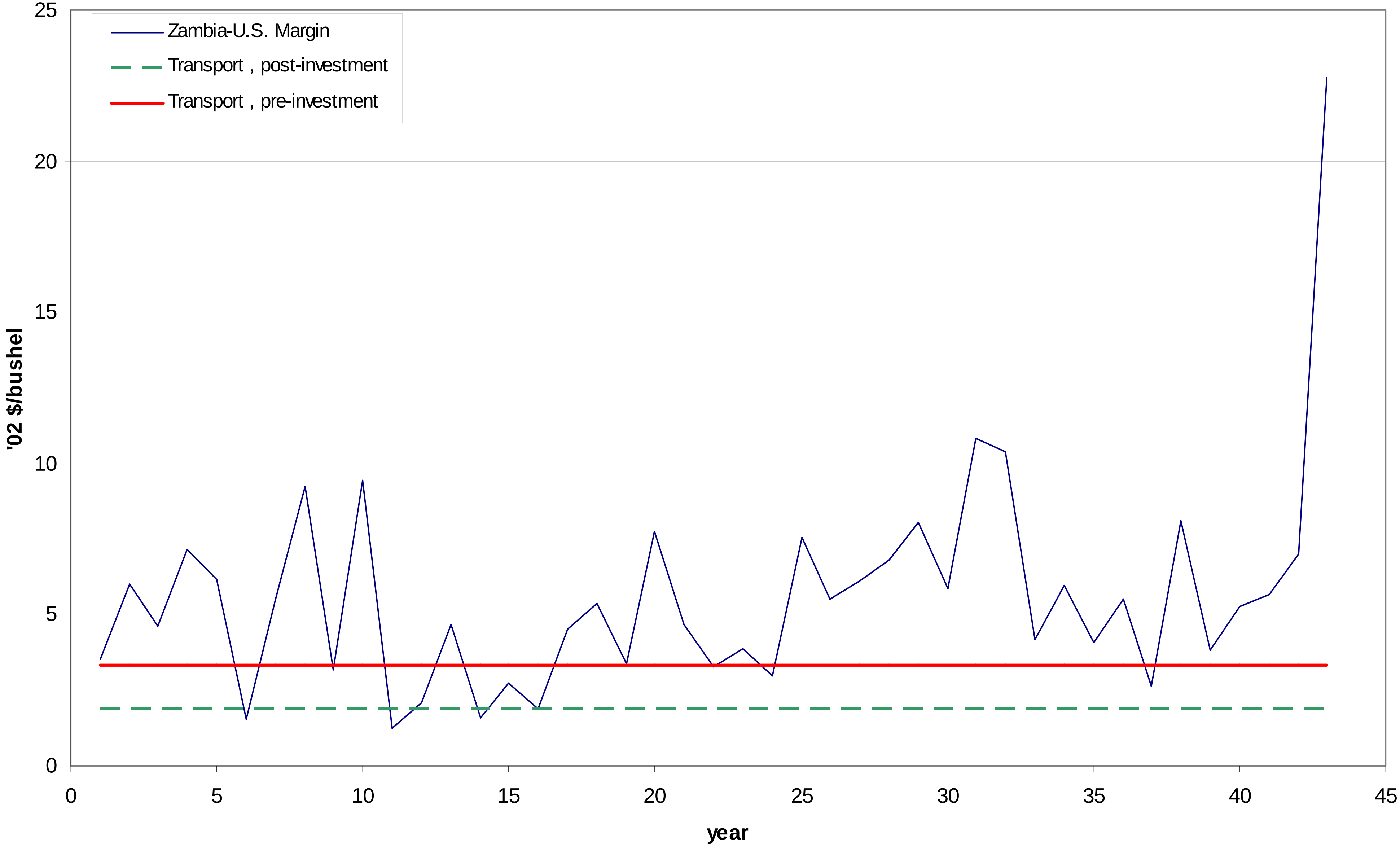


Figure 5. U.S.: Zambia White Maize Marketing: Returns and Costs



Appendix A: Regression Estimates for the Equations of Table 1[1]

Zambia Maize Acreage Response

$$A_t = 126{,}246 + 25.3958\,P_{z_t} - 0.02721\ R_t + 0.80024\,A_{t-1}$$

(1.69) (1.73) (1.63) (6.93)

$\overline{R}^2 = 0.7038 \quad D.W. = 2.09 \quad \overline{S} = 114{,}434 \quad \overline{A} = 709{,}164$

Zambia Maize Yield Response

$$y_t = 627.75243 + 23.93503\,f - 0.744497\,f^2 + 8.0529\,T$$

$\overline{R}^2 = .482 \quad D.W. = 2.153 \quad \overline{s} = 354.01 \quad \overline{y} = 1438.5$

Note: $f_t = F_t/A_t$

Maize Demand per Capita

$$\frac{D}{N} = 110.07414 - 0.00677\ P_{z_t} + 0.0000160\ \ GDP_t\ /\ N_t$$

(28.26) (2.27) (11.16)

$\overline{R}^2 = .8542 \quad D.W. = 1.47 \quad \overline{s} = 4.21 \quad \overline{y} = 138.99$

Zambia-So. Africa Price Transmission (1993 to 2004)

$$R_{mz_t} = 71.44269\ \frac{1}{CP_{z_t}} + 0.00126\ D_{p_t} \bullet M_t$$

(2.45) (3.22)

$\overline{R}^2 = 0.6186 \quad D.W. = \quad \overline{s} = 189.53 \quad \overline{y} = 172.45$

Note: There are two observations each year, the planting period and the harvest period. Calendar year maize import data is used, assuming that the imports occur during the planting period.

$$R_{mz_t} = P_{z_t} - P_{a_t} \bullet E_{a_t}$$

$$D_{p_t} = \begin{cases} 0; & during\ \ So.hemisphere\ \ harvest\ \ period\ \ (Apr.to\ Sep) \\ 1; & during\ \ So.hemisphere\ \ plant\ \ period\ \ (Oct.to\ Mar) \end{cases}$$

$$M_t = Zambia's\ maize\ imports\ during\ \ calendar\ \ year,\ in\ 1{,}000\ mt.$$

$$CP_{z_t} = CPI\ in\ Zambia, '02 = 1.0$$
$$CP_{a_t} = CPI\ in\ So.Africa, '02 = 1.0$$

U.S.-So. Africa Price Transmission

$$R_{ma_t} = 0.23053\frac{1}{CP_{a_t}}$$

$\overline{R}^2 = .5482 \quad D.W. = \quad \overline{s} = 0.2781 \quad \overline{y} = 0.2830$

$$R_{ma_t} = P_{a_t} - Pu_{a_t} \bullet Eu_{a_t}$$

[1] Variable definitions are given in table 1, unless noted otherwise.

Appendix B: Trend/Autoregressions for Exogenous Variables[1]

Real Fertilizer Price

$$P_{f_t} = 2491 - 134.39t + 0.6077\ U_{t-1}$$

$$\bar{R}^2 = 0.4319 \quad D.W. = 1.88 \quad \bar{s} = 3533 \quad \bar{y} = 3722.59$$

Real GDP

$$\underset{}{\Delta G_t} = \underset{(3.40)}{0.24435} + \underset{(3.07)}{0.01148T} - \underset{(3.76)}{0.19180\,D88_t}$$

$$\bar{R}^2 = 0.3661 \quad D.W. = 2.065 \quad \bar{s} = 0.06575 \quad \bar{y} = -0.007$$

$$\Delta G_t = \ell n(GDP_t) - \ell n(GDP_{t-1}) \doteq \textit{Percentage change in real GDP growth}$$

$$D88_t = \begin{cases} 0; \textit{ until } 1987 \\ 1; \textit{ beginning in } 1988 \end{cases}$$

So. African Real Exchange Rate (1971 to 2004)

$$Eu_t = \underset{(11.56)}{6.9406} + \underset{(3.08)}{0.1029t} + \underset{(4.13)}{0.59541\ U_{t-1}}$$

$$\bar{R}^2 = 0.6967 \quad D.W. = 1.55 \quad \bar{s} = 0.874 \quad \bar{y} = 5.45$$

Zambia Real Exchange Rate (1971 to 2004)

$$E_{a_t} = \underset{(4.61)}{669.2395} - \underset{(0.71)}{5.634\,t} + \underset{(4.41)}{0.6275U_{t-1}}$$

$$\bar{R}^2 = 0.4197 \quad D.W. = 1.58 \quad \bar{s} = 186.75 \quad \bar{y} = 761.16$$

Real Corn Price

$$P_{u_t} = \underset{(12.31)}{0.3270} - \underset{(6.83)}{0.07326\ \ln(T+22)}$$

$$\bar{R}^2 = 0.6894 \quad D.W. = 1.79 \quad \bar{s} = 0.3465 \quad \bar{y} = 0.15$$

[1] Variable definitions given in table 1, unless noted otherwise. The Yule-Walker method is used for autocorrelations.